Λ_c^+ Decays at BESIII

Lei Li

For BESIII Collaboration

Beijing Institute of Petro-chemical Technology (BIPT)

中国物理学会高能物理分会/第十二届全国粒子物理学术会议

Aug. 22-26, 2016, Hefei, China

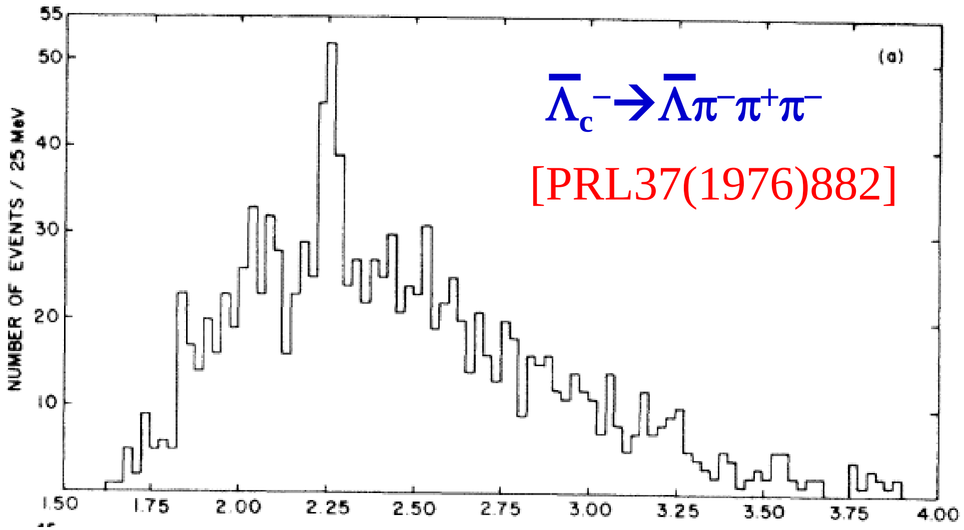
Outline

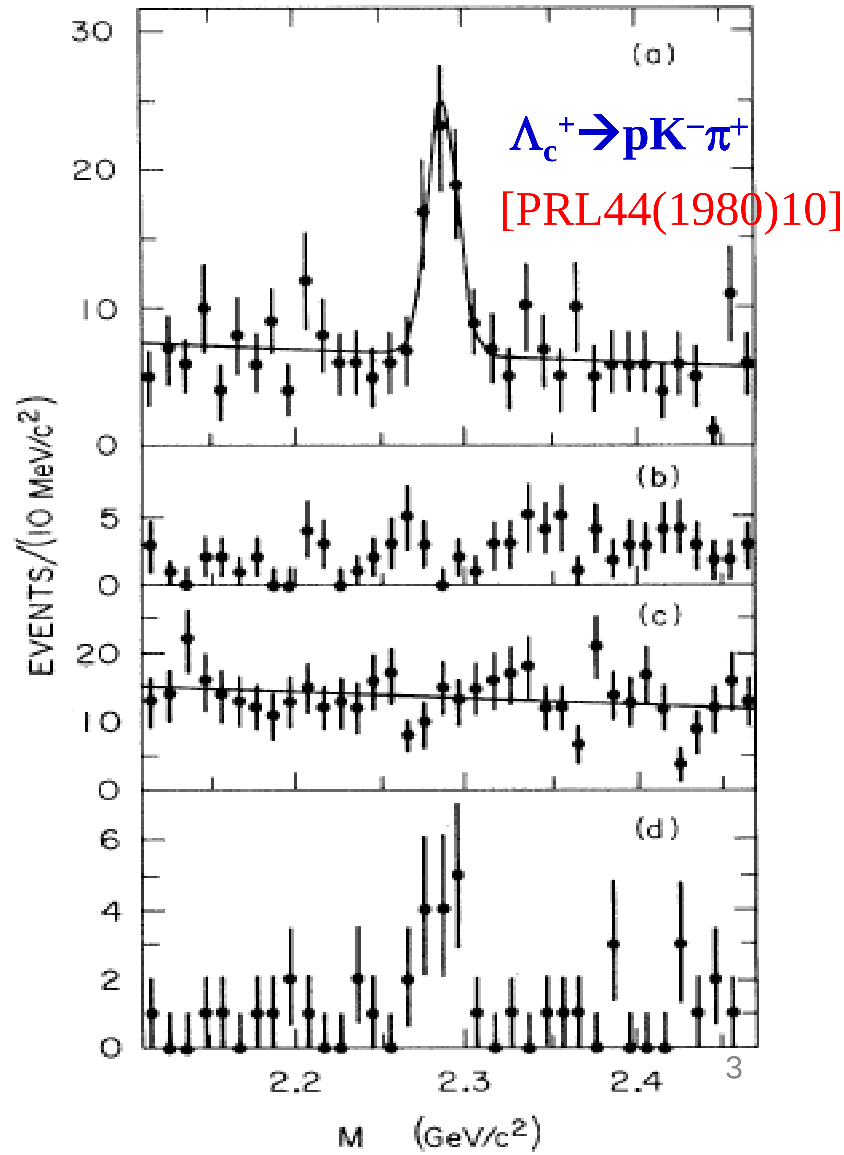
- Introduction
- Λ_c^+ decays
  - Λ_c^+ semi-leptonic decays
  - Λ_c^+ hadronic decays
- Summary

Discovery of Λ_c^+

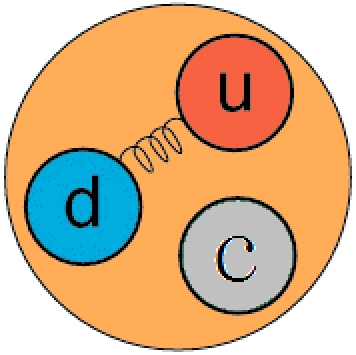
■ Λ_c^+ was first observed of at Fermi Lab in 1976 and then established at Mark II experiment in 1980.

Invariant mass distribution





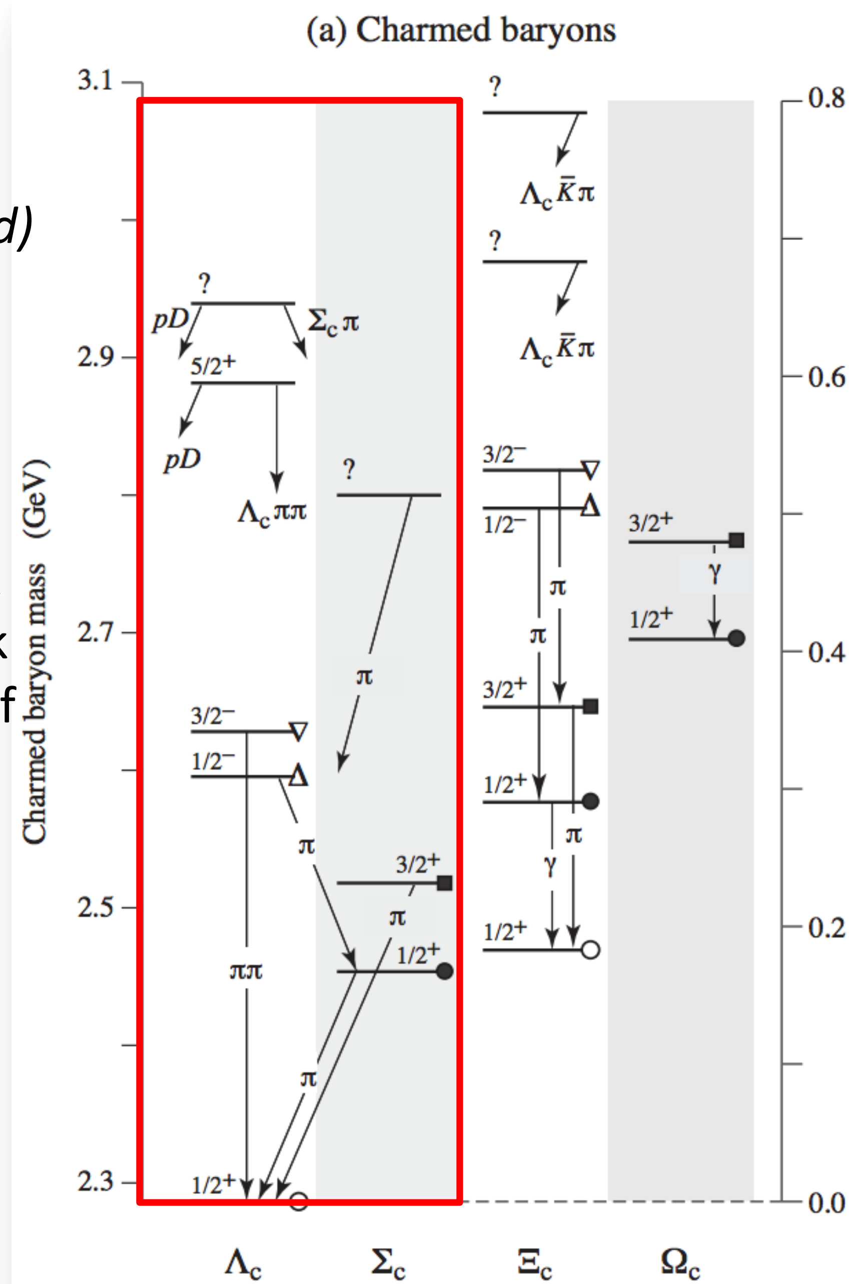
Λ_c^+ cornerstone of charmed baryon spectroscopy



Quark model picture:
a heavy quark (c) with a unexcited spin-zero diquark (u-d)

Heavy Quark Effective Theory:
✓diquark correlation is enhanced by weak Color Magnetic Interaction with a heavy quark
✓more reliable prediction of heavy-light quark transition without dealing with light degrees of freedom that have net spin or isospin.

Λ_c^+ may provides more powerful test on internal dynamic than D/Ds does.



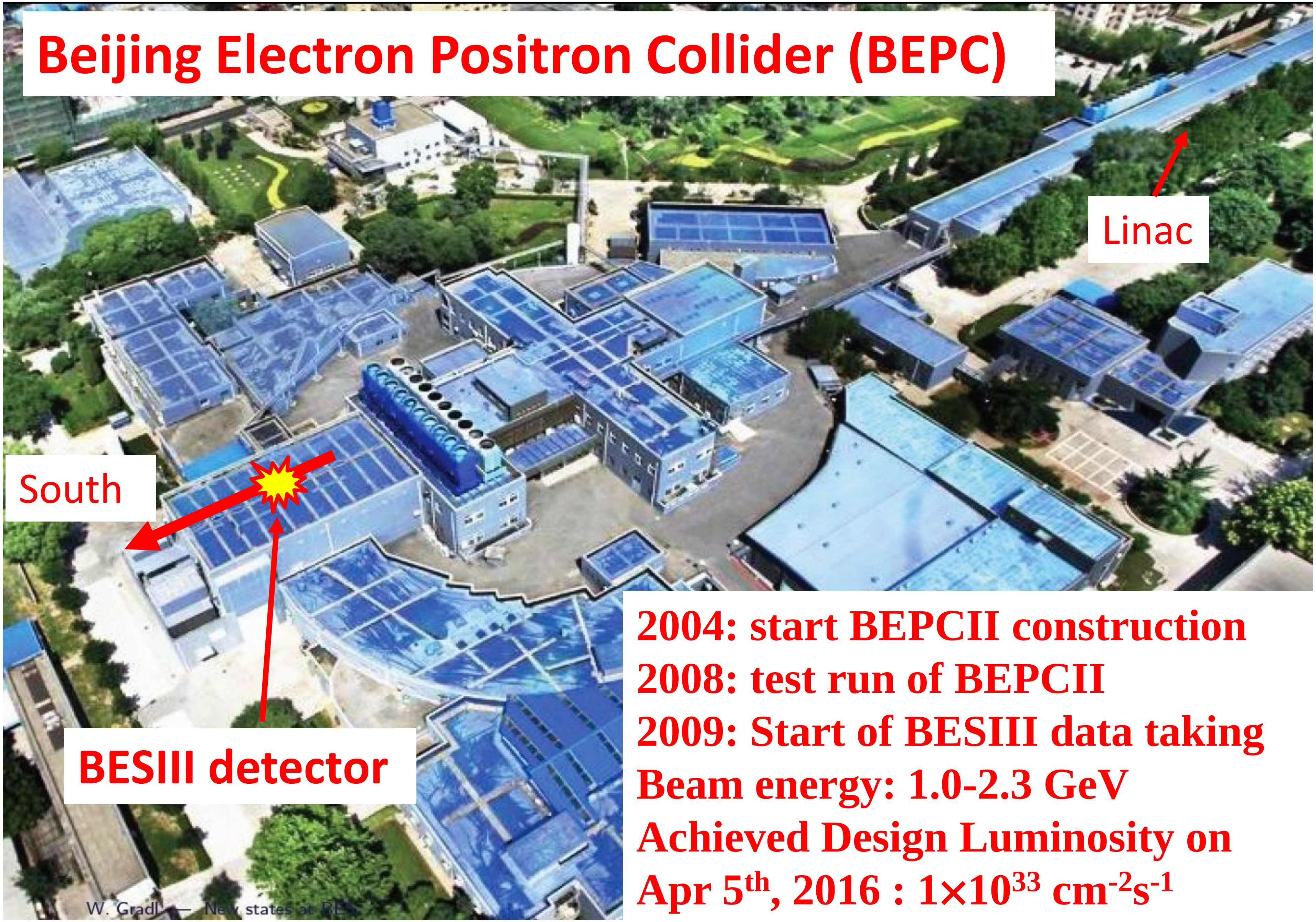
Λ_c^+ Measurements [PDG2015]

Λ_c^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)	ΔB/B
Hadronic modes with a p: $S = -1$ final states					
$p\overline{K}^0$		(3.21 ± 0.30) %			9.3%
$pK^-\pi^+$		$(6.84^{+0.32}_{-0.40})$ %			5.8%
$p\overline{K}^*(892)^0$	[q]	(2.13 ± 0.30) %			14.1%
$\Delta(1232)^{++}K^-$		(1.18 ± 0.27) %			22.9%
$\Lambda(1520)\pi^+$	[q]	(2.4 ± 0.6) %			25.0%
$pK^-\pi^+$ nonresonant		(3.8 ± 0.4) %			10.5%
$p\overline{K}^0\pi^0$		(4.5 ± 0.6) %			13.3%
$p\overline{K}^0\eta$		(1.7 ± 0.4) %			23.5%
$p\overline{K}^0\pi^+\pi^-$		(3.5 ± 0.4) %			11.4%
$pK^-\pi^+\pi^0$		(4.6 ± 0.8) %			13.0%
$pK^*(892)^-\pi^+$	[q]	(1.5 ± 0.5) %			33.3%
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(5.0 ± 0.9) %			18.0%
$\Delta(1232)\overline{K}^*(892)$		seen			
$pK^-\pi^+\pi^+\pi^-$		$(1.5 \pm 1.0) \times 10^{-3}$			66.7%
$pK^-\pi^+\pi^0\pi^0$		(1.1 ± 0.5) %			45.4%
Hadronic modes with a p: $S = 0$ final states					
$p\pi^+\pi^-$		$(4.7 \pm 2.5) \times 10^{-3}$			45.4%
$pf_0(980)$	[q]	$(3.8 \pm 2.5) \times 10^{-3}$			53.2%
$p\pi^+\pi^+\pi^-\pi^-$		$(2.5 \pm 1.6) \times 10^{-3}$			64.0%
pK^+K^-		$(1.1 \pm 0.4) \times 10^{-3}$			36.4%
$p\phi$	[q]	$(1.12 \pm 0.23) \times 10^{-3}$			
pK^+K^- non-ϕ		$(4.8 \pm 1.9) \times 10^{-4}$			
Hadronic modes with a hyperon: $S = -1$ final states					
$\Lambda\pi^+$		(1.46 ± 0.13) %			8.9%
$\Lambda\pi^+\pi^0$		(5.0 ± 1.3) %			26.0%
$\Lambda\rho^+$		< 6 %	CL=95%		
$\Lambda\pi^+\pi^+\pi^-$		(3.59 ± 0.28) %			7.8%
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+} \to \Lambda\pi^+$		(1.0 ± 0.5) %			20.0%
$\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-} \to \Lambda\pi^-$		$(7.5 \pm 1.4) \times 10^{-3}$			18.7%

				ΔB/B
$\Lambda\pi^+\rho^0$		(1.4 ± 0.6) %		42.8%
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+} \to \Lambda\pi^+$		$(5 \pm 4) \times 10^{-3}$		80.0%
$\Lambda\pi^+\pi^+\pi^-$ nonresonant		< 1.1 %	CL=90%	
$\Lambda\pi^+\pi^+\pi^-\pi^0$ total		(2.5 ± 0.9) %		36.0%
$\Lambda\pi^+\eta$	[q]	(2.4 ± 0.5) %		20.8%
$\Sigma(1385)^+\eta$	[q]	(1.16 ± 0.35) %		30.2%
$\Lambda\pi^+\omega$	[q]	(1.6 ± 0.6) %		37.5%
$\Lambda\pi^+\pi^+\pi^-\pi^0$, no η or ω		$< 9 \times 10^{-3}$	CL=90%	
$\Lambda K^+\overline{K}^0$		$(6.4 \pm 1.3) \times 10^{-3}$	S=1.6	20.3%
$\Xi(1690)^0K^+$, $\Xi^{*0} \to \Lambda\overline{K}^0$		$(1.8 \pm 0.6) \times 10^{-3}$		33.3%
$\Sigma^0\pi^+$		(1.43 ± 0.14) %		10.0%
$\Sigma^+\pi^0$		(1.37 ± 0.30) %		21.9%
$\Sigma^+\eta$		$(7.5 \pm 2.5) \times 10^{-3}$		33.3%
$\Sigma^+\pi^+\pi^-$		(4.9 ± 0.5) %		10.2%
$\Sigma^+\rho^0$		< 1.8 %	CL=95%	
$\Sigma^-\pi^+\pi^+$		(2.3 ± 0.4) %		17.4%
$\Sigma^0\pi^+\pi^0$		(2.5 ± 0.9) %		36.0%
$\Sigma^0\pi^+\pi^+\pi^-$		(1.13 ± 0.31) %		27.4%
$\Sigma^+\pi^+\pi^-\pi^0$		—		
$\Sigma^+\omega$	[q]	(3.7 ± 1.0) %		27.1%
$\Sigma^+K^+K^-$		$(3.8 \pm 0.6) \times 10^{-3}$		15.8%
$\Sigma^+\phi$	[q]	$(4.3 \pm 0.7) \times 10^{-3}$		16.3%
$\Xi(1690)^0K^+$, $\Xi^{*0} \to \Sigma^+K^-$		$(1.11 \pm 0.29) \times 10^{-3}$		26.2%
$\Sigma^+K^+K^-$ nonresonant		$< 9 \times 10^{-4}$	CL=90%	
Ξ^0K^+		$(5.3 \pm 1.3) \times 10^{-3}$		24.5%
$\Xi^-K^+\pi^+$		$(7.0 \pm 0.8) \times 10^{-3}$	S=1.1	11.4%
$\Xi(1530)^0K^+$	[q]	$(3.5 \pm 1.0) \times 10^{-3}$		28.6%
Hadronic modes with a hyperon: $S = 0$ final states				
ΛK^+		$(6.9 \pm 1.4) \times 10^{-4}$		20.3%
$\Lambda K^+\pi^+\pi^-$		$< 6 \times 10^{-4}$	CL=90%	
Σ^0K^+		$(5.7 \pm 1.0) \times 10^{-4}$		17.5%
$\Sigma^0K^+\pi^+\pi^-$		$< 2.9 \times 10^{-4}$	CL=90%	
$\Sigma^+K^+\pi^-$		$(2.3 \pm 0.7) \times 10^{-3}$		30.4%
$\Sigma^+K^*(892)^0$	[q]	$(3.8 \pm 1.2) \times 10^{-3}$		31.6%
$\Sigma^-K^+\pi^+$		$< 1.3 \times 10^{-3}$	CL=90%	
Doubly Cabibbo-suppressed modes				
$pK^+\pi^-$		$< 3.1 \times 10^{-4}$	CL=90%	
Semileptonic modes				
$\Lambda\ell^+\nu_\ell$	[r]	(2.8 ± 0.4) %		
$\Lambda e^+\nu_e$		(2.9 ± 0.5) %		17.2%
$\Lambda\mu^+\nu_\mu$		(2.7 ± 0.6) %		22.2%

- ✓ Total branching fraction small than 65%.
- ✓ Lots of unknown decay channels
- ✓ Quite large uncertainties, most larger than 20%
- ✓ Most BFs are measured relative to $\Lambda_c^+ \to pK^-\pi^+$

Beijing Electron Positron Collider (BEPC)



2004: start BEPCII construction
2008: test run of BEPCII
2009: Start of BESIII data taking
Beam energy: 1.0-2.3 GeV
Achieved Design Luminosity on Apr 5th, 2016 : 1×10^{33} cm^{-2}s^{-1}

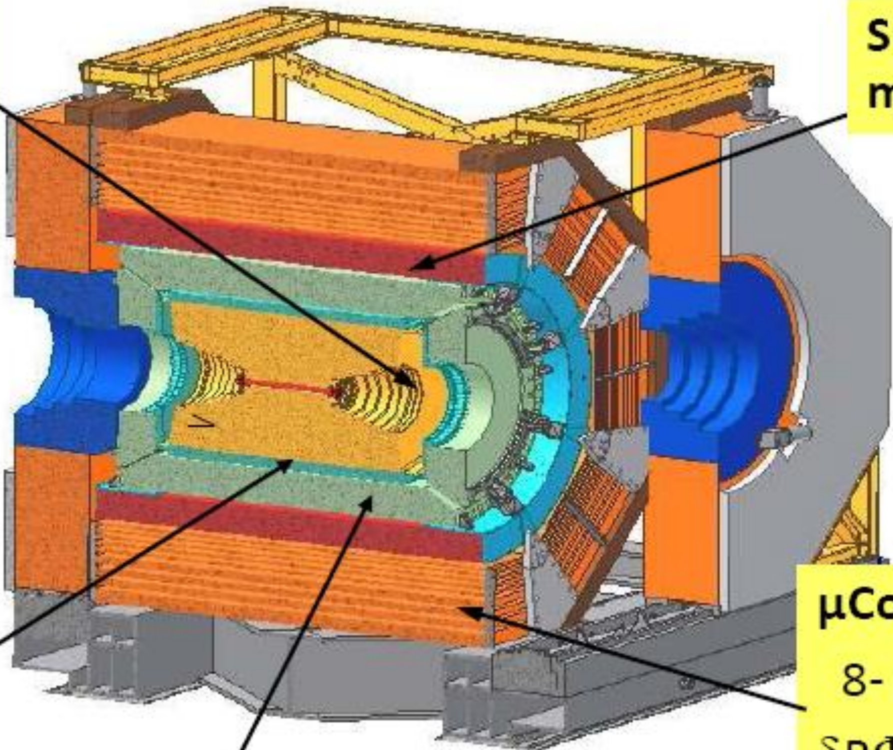
BESIII Detector

Drift Chamber (MDC)

$\sigma P/P\ (^0/_0) = 0.5\%(1GeV)$

$\sigma_{dE/dx}\ (^0/_0) = 6\%$

Super-conducting magnet (1.0 tesla)



Time Of Flight (TOF)

σ_T: 90 ps Barrel
110 ps endcap

μCounter

8- 9 layers RPC

$\delta R\Phi$=1.4 cm~1.7 cm

EMC: $\sigma E/\sqrt{E}(^0/_0) = 2.5\ \%\ (1\ GeV)$

(CsI) $\sigma_{z,\phi}(cm) = 0.5 - 0.7\ cm/\sqrt{E}$

Data samples at BESIII

In 2014, BESIII collected data above Λ_c pair threshold and run machine at 4.599 GeV with excellent performance.

Energy (GeV)	Luminosity (pb^{-1})
4.575	~48
4.580	~8.5
4.590	~8.1
4.599	~567

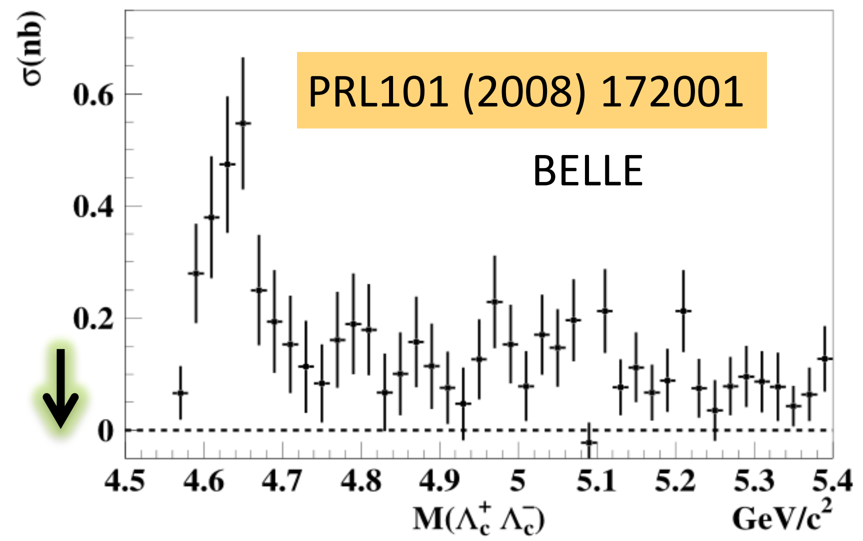


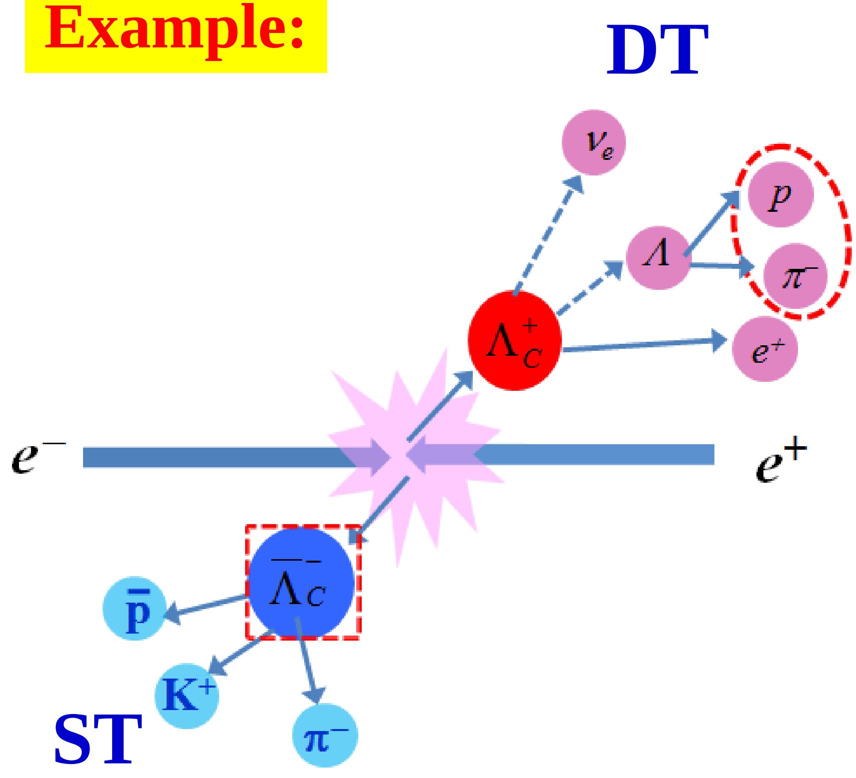
FIG. 4: The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

In the future, it is possible that BESIII can collect Λ_c data at high energies, for example 4.64 GeV or more high energies.

It is time to systematically study the decay property of Λ_c at BESIII.

Analysis Technique

Example:



✓Single Tags (ST)

$$M_{\rm BC} = \sqrt{E^2_{\rm beam} - |\vec{p}_{\bar{\Lambda}_c^-}|^2}$$

✓Double Tags (DT)

$$U_{\rm miss} = E_{\rm miss} - c|\vec{p}_{\rm miss}|$$

✓Branching Fraction (BF)

$$\mathcal{B}_{\rm SL} = \frac{N^{\rm semi}}{N^{\rm tag} \times \epsilon}$$

Clean sample of ST charmed baryons can be fully reconstructed by hadronic decays with large BFs. Based on this, one can access to absolute BFs and dynamics in the decays.

Singly Tagged $\bar{\Lambda}_c^-$ baryons

The singly tagged $\bar{\Lambda}_c^-$ baryons are reconstructed by:

- $\Lambda_c^- \to \bar{p}K_S^0$, $\Lambda_c^- \to \bar{p}K^+\pi^-$
- $\Lambda_c^- \to \bar{p}K_S^0\pi^0$, $\Lambda_c^- \to \bar{p}K^+\pi^-\pi^0$,
- $\Lambda_c^- \to \bar{p}K_S^0\pi^+\pi^-$, $\Lambda_c^- \to \bar{\Lambda}\pi^-$,
- $\Lambda_c^- \to \bar{\Lambda}\pi^-\pi^0$, $\Lambda_c^- \to \bar{\Lambda}\pi^-\pi^+\pi^-$,
- $\Lambda_c^- \to \bar{\Sigma}^0\pi^-$, $\Lambda_c^- \to \bar{\Sigma}^-\pi^0$ and $\Lambda_c^- \to \bar{\Sigma}^-\pi^+\pi^-$,

with

- $K_S^0 \to \pi^+\pi^-$,
- $\bar{\Lambda} \to \bar{p}\pi^+$,
- $\bar{\Sigma}^0 \to \gamma\bar{\Lambda}$ with $\bar{\Lambda} \to \bar{p}\pi^+$,
- $\bar{\Sigma}^- \to \bar{\Lambda}\pi^-$,
- $\pi^0 \to \gamma\gamma$.

Singly Tagged $\bar{\Lambda}_c^-$ baryons

Summary of the BFs for 11 single tags: PDG2015

$p\overline{K}^0$	(3.21 ± 0.30) %
$pK^-\pi^+$	$(6.84 {}^{+0.32}_{-0.40})$ %
$p\overline{K}^0\pi^0$	(4.5 ± 0.6) %
$p\overline{K}^0\pi^+\pi^-$	(3.5 ± 0.4) %
$pK^-\pi^+\pi^0$	(4.6 ± 0.8) %
$\Lambda\pi^+$	(1.46 ± 0.13) %
$\Lambda\pi^+\pi^0$	(5.0 ± 1.3) %
$\Lambda\pi^+\pi^+\pi^-$	(3.59 ± 0.28) %
$\Sigma^0\pi^+$	(1.43 ± 0.14) %
$\Sigma^+\pi^0$	(1.37 ± 0.30) %
$\Sigma^+\pi^+\pi^-$	(4.9 ± 0.5) %

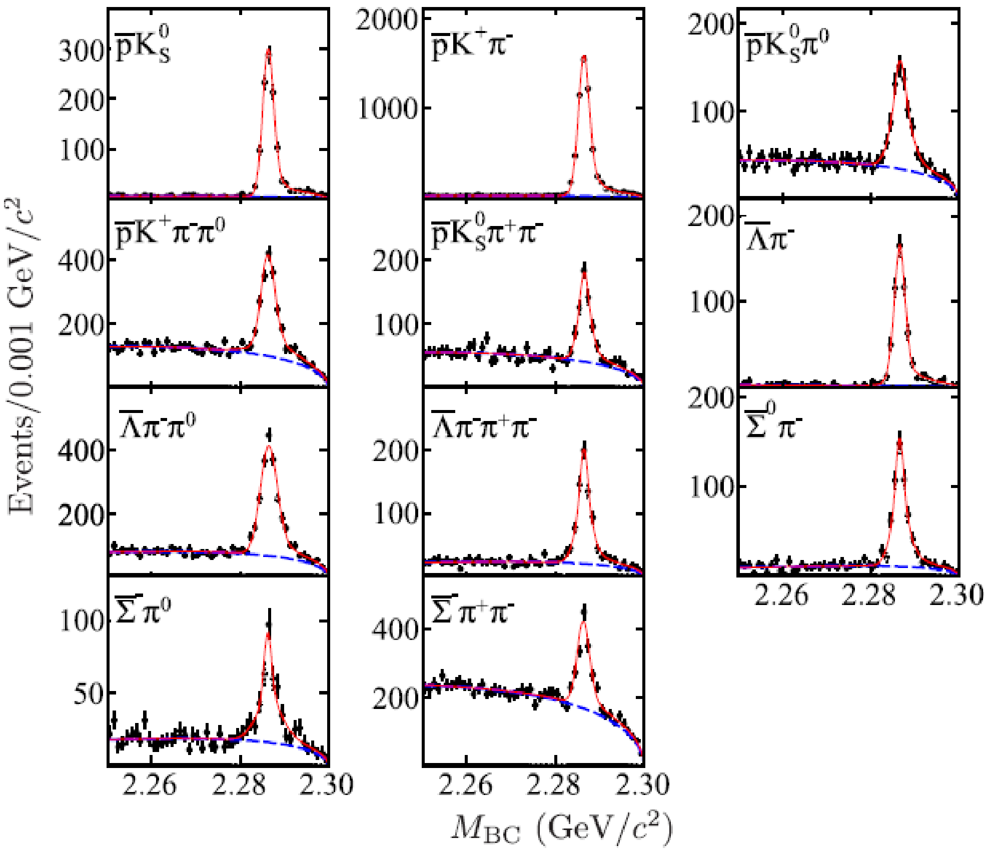
~40%

Currently, the total measured BFs for Λ_c^+ is less than 65%.

Singly Tagged $\bar{\Lambda}_c^-$ baryons

- M_{BC} distributions for 11 single tags

$$M_{BC} = \sqrt{E_{beam}^2 - |\vec{p}_{\bar{\Lambda}_c^-}|^2}$$

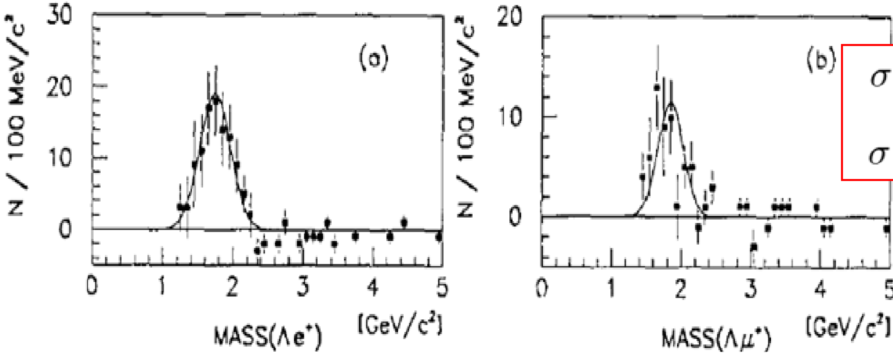


Mode	ΔE (GeV)	$N_{\bar{\Lambda}_c^-}$
$\bar{p}K_S^0$	[−0.025, 0.028]	1066 ± 33
$\bar{p}K^+\pi^-$	[−0.019, 0.023]	5692 ± 88
$\bar{p}K_S^0\pi^0$	[−0.035, 0.049]	593 ± 41
$\bar{p}K^+\pi^-\pi^0$	[−0.044, 0.052]	1547 ± 61
$\bar{p}K_S^0\pi^+\pi^-$	[−0.029, 0.032]	516 ± 34
$\bar{\Lambda}\pi^-$	[−0.033, 0.035]	593 ± 25
$\bar{\Lambda}\pi^-\pi^0$	[−0.037, 0.052]	1864 ± 56
$\bar{\Lambda}\pi^-\pi^+\pi^-$	[−0.028, 0.030]	674 ± 36
$\bar{\Sigma}^0\pi^-$	[−0.029, 0.032]	532 ± 30
$\bar{\Sigma}^-\pi^0$	[−0.038, 0.062]	329 ± 28
$\bar{\Sigma}^-\pi^+\pi^-$	[−0.049, 0.054]	1009 ± 57

ST yields: 14415±159 events with 11 ST modes

$\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ decays

- In 1991, ARGUS reported the first measurement of $\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ with 477 pb^{-1} $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(4S)$ data

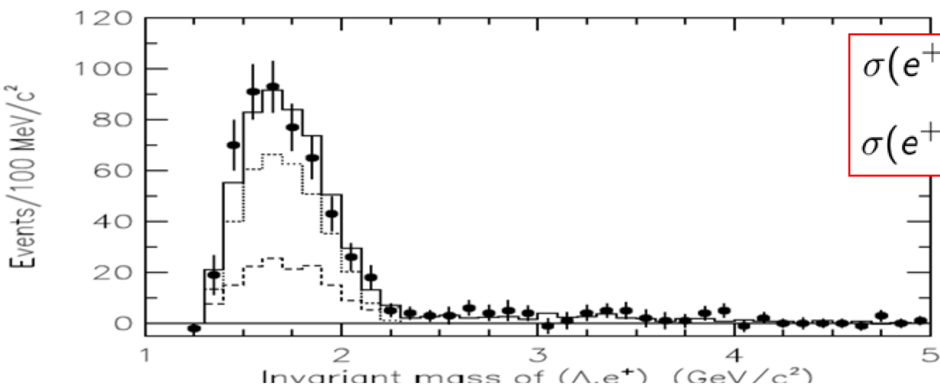


$$\sigma(e^+e^- \to \Lambda_c^+ X)\cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda e^+ X) = 4.20 \pm 1.28 \pm 0.71 \text{ pb}$$

$$\sigma(e^+e^- \to \Lambda_c^+ X)\cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda \mu^+ X) = 3.91 \pm 2.02 \pm 0.90 \text{ pb}$$

Phys. Lett. B 269, 234 (1991).

- In 1994, CLEO performed same measurement with 1.6 fb^{-1} $\Upsilon(4S)$ data



$$\sigma(e^+e^- \to \Lambda_c^+ X)\cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda e^+ X) = 4.87 \pm 0.28 \pm 0.69 \text{ pb}$$

$$\sigma(e^+e^- \to \Lambda_c^+ X)\cdot \mathrm{BR}(\Lambda_c^+ \to \Lambda \mu^+ X) = 4.43 \pm 0.51 \pm 0.64 \text{ pb}$$

Phys. Lett. B 323, 219 (1994).

- Based on above two measurements , PDG extracts BF for $\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ with $\tau(\Lambda_c^+)$ and the assumption of form factors

$\Lambda \ell^+ \nu_\ell$	[r]	(2.8 ± 0.4) %
$\Lambda e^+ \nu_e$		(2.9 ± 0.5) %
$\Lambda \mu^+ \nu_\mu$		(2.7 ± 0.6) %

Not a direct measurement!

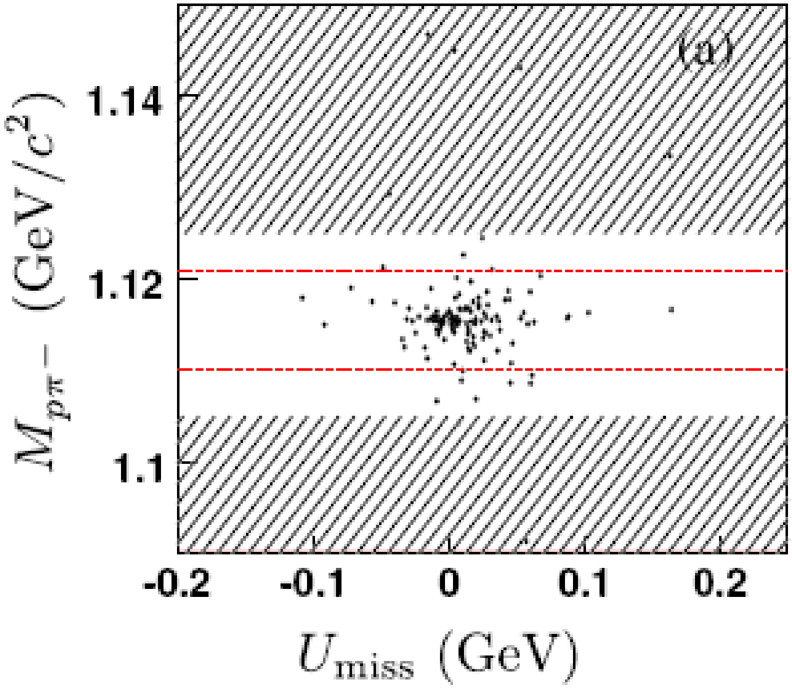
$\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$ decays

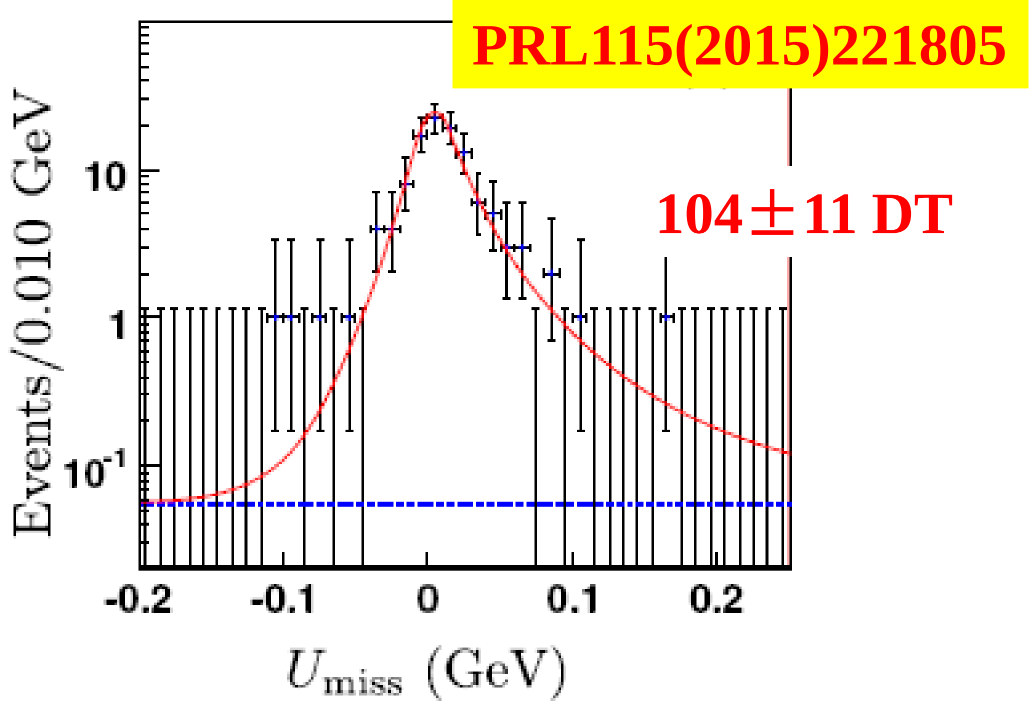
Theoretical calculations on the BF ranges from 1.4% to 9.2%

PDG2014: (2.1±0.6)%

PDG2015: (2.9±0.5)%

Input $B[\Lambda_C^+ \rightarrow pK^-\pi^+]=(6.84^{+0.32}_{-0.40})\%$ by BELLE [PRL113,042002(2014)]





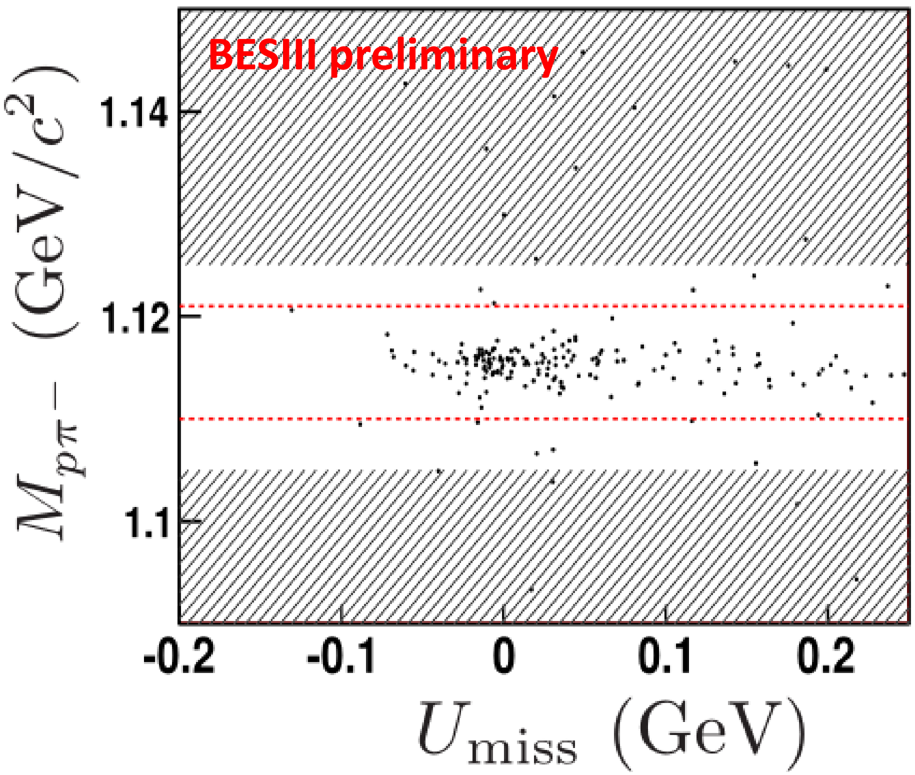
$B[\Lambda_c^+ \rightarrow \Lambda e^+ v]=(3.63\pm0.38\pm0.20)\%$ **First absolute measurement**

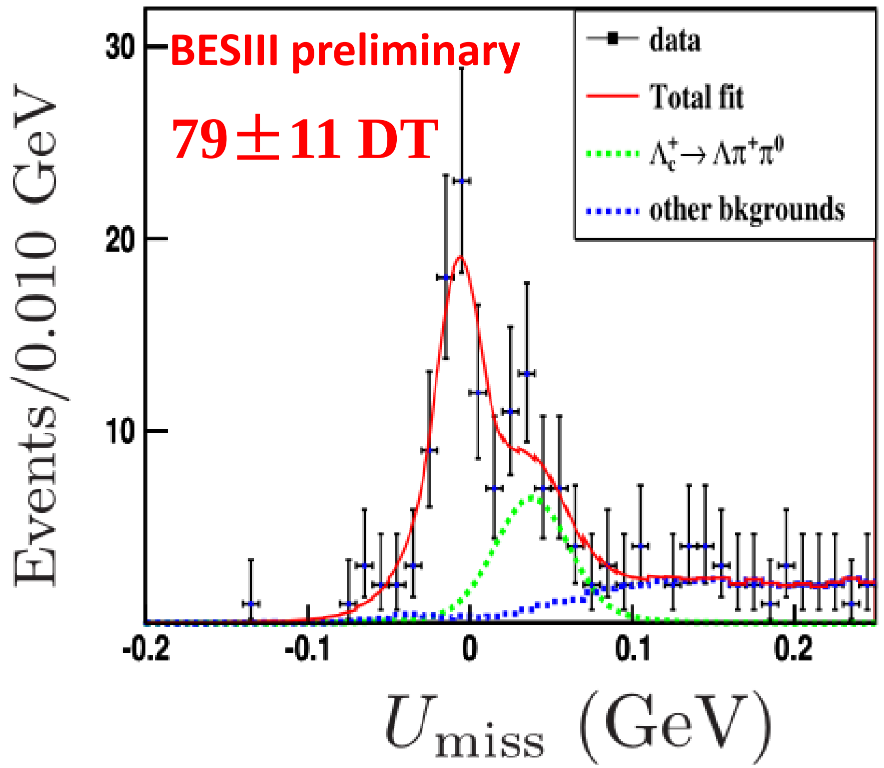
Important for test and calibrate the LQCD calculations.

Model &Experiment	Br^{exp} [%]	References
SU(4) symmetry limit	9.2	M. Avila-Aoki et al [PRD40, 2944 (1989)]
Non-relativistic quark model	2.6	Perez-Marcial et al [PRD40, 2955 (1989)]
MIT bag model [MBM]	1.9	Perez-Marcial et al [PRD40, 2955 (1989)]
Relativistic spectator Model	4.4	F. Hussain et al [ZPC51, 607 (1991)]
Spectator quark model	1.96	Robert Singleton, Jr. [PRD43, 2939(1991)]
Quark confinement Model	5.62	G. V. Efimov et al [ZPC52, 149 (1991)]
Non-relativistic quark model	2.15	A. Garcia et al [PRD45, 3266 (1992)]
Non-relativistic quark model	1.42	H. Y. Cheng et al [PRD53, 1457 (1995)]
QCD Sum Rule	3.0±0.9	H. G. Dosch et al [PLB431, 173 (1998)]
QCD Sum Rule	2.6±0.4	R. S. Marques de Carvalho et al [PRD60, 034009 (1999)]
QCD Sum Rule	5.8±1.5	
HOSR	4.72	M. Pervin et al [PRC72, 035201 (2005)]
HONR	4.2	
STSR	2.22	
STNR	1.58	
LCSRs	3.0±0.3 (CZ-type) 2.0±0.3(Ioffe-type)	Y. L. Liu, M.Q. Huang and D. W. Wang [PRD80, 074011 (2009)]
Convariant confined quark model	2.78	Thomas Gutsche et al [PRD93, 034008(2016)]
BESIII [First absolute measurement]	3.63±0.43	PRL 115, 221805 (2015)]

$\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$ decays

Theoretical calculations on the BF ranges from 1.4% to 9.2%





First absolute measurement

- **Preliminary results:**

$B[\Lambda_c^+ \to \Lambda\mu^+\nu_\mu] = (3.49 \pm 0.46 \pm 0.26)\%$

$\Gamma[\Lambda_c^+ \to \Lambda\mu^+\nu_\mu]/\Gamma[\Lambda_c^+ \to \Lambda e^+\nu_e] = 0.96 \pm 0.16 \pm 0.04$

where the first error is statistical and the second systematic.

Search for $\Lambda_c^+ \rightarrow \Lambda^* l^+ \nu_l$

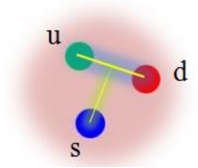
- If Λ_c^+ is J=1/2, it favors the decay $\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$.

Λ_c^+ $I(J^P) = 0(\frac{1}{2}^+)$

J is not well measured; $\frac{1}{2}$ is the quark-model prediction.

Mass $m = 2286.46 \pm 0.14$ MeV
Mean life $\tau = (200 \pm 6) \times 10^{-15}$ s (S = 1.6)
$c\tau = 59.9\ \mu$m

B[$\Lambda_c^+ \rightarrow \Lambda^* l^+ \nu_l$]<<B[$\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$] ?



suggestive of di-quark model

- Searching for $\Lambda_c^+ \rightarrow \Lambda^* l^+ \nu_l$ is quite important.

$\Lambda(1405)$ 1/2$^-$ $I(J^P) = 0(\frac{1}{2}^-)$

Mass $m = 1405.1^{+1.3}_{-1.0}$ MeV
Full width $\Gamma = 50.5 \pm 2.0$ MeV
Below $\overline{K}N$ threshold

$\Lambda(1405)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma\pi$	100 %	155

$\Lambda(1520)$ 3/2$^-$ $I(J^P) = 0(\frac{3}{2}^-)$

Mass $m = 1519.5 \pm 1.0$ MeV [o]
Full width $\Gamma = 15.6 \pm 1.0$ MeV [o]

$\Lambda(1520)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	(45 ±1) %	243
$\Sigma\pi$	(42 ±1) %	268
$\Lambda\pi\pi$	(10 ±1) %	259
$\Sigma\pi\pi$	(0.9 ±0.1) %	169
$\Lambda\gamma$	(0.85±0.15) %	350

$\Lambda(1600)$ 1/2$^+$ $I(J^P) = 0(\frac{1}{2}^+)$

Mass m = 1560 to 1700 (≈ 1600) MeV
Full width Γ = 50 to 250 (≈ 150) MeV
$p_{beam} = 0.58$ GeV/c $4\pi\lambda\!\!\!^-{}^2 = 41.6$ mb

$\Lambda(1600)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	15–30 %	343
$\Sigma\pi$	10–60 %	338

$\Lambda(1670)$ 1/2$^-$ $I(J^P) = 0(\frac{1}{2}^-)$

Mass m = 1660 to 1680 (≈ 1670) MeV
Full width Γ = 25 to 50 (≈ 35) MeV
$p_{beam} = 0.74$ GeV/c $4\pi\lambda\!\!\!^-{}^2 = 28.5$ mb

$\Lambda(1670)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	20–30 %	414
$\Sigma\pi$	25–55 %	394
$\Lambda\eta$	10–25 %	69
$N\overline{K}^*(892)$, S=3/2, D-wave	(5±4) %	†

$\Lambda^* \rightarrow pK^-/\Sigma\pi$

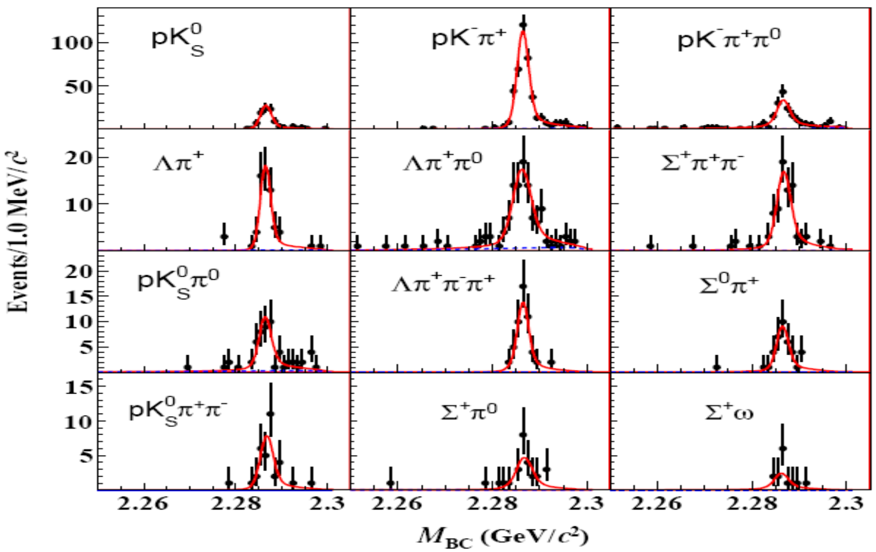
channel	N. Ikeno et al. [PRD93, 14021]	M. Pervin et al [PRC72, 035201]
$\Lambda_c^+ \rightarrow \Lambda(1405)\ e^+\nu_e$	2×10^{-5}	0. 6%
$\Lambda_c^+ \rightarrow \Lambda(1520)\ e^+\nu_e$	– –	0. 1%

Some theories suggested that the weak decay processes are important to clarify the existence and the nature of *Λ(1405)*. *Thus, study of* $\Lambda_c^+ \rightarrow \Lambda(1405) l^+ \nu_l$ is very important.

Absolute BFs for Λ_c^+ hadron decays

Measurement using the threshold pair-productions via e^+e^- annihilation is unique: the most simple and straightforward

PRL116(2016)052001



A global least-square fitter is utilized to improve the measured precision for 12 Λ_c^+ hadronic decay channels.

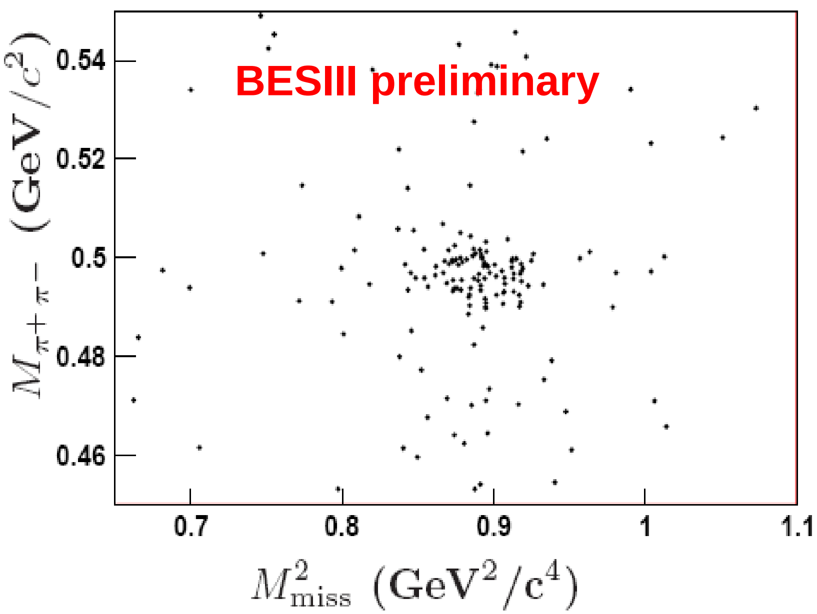
$$N_{-j}^{DT} = \sum_{i^+ \neq i} N_{i+j-}^{DT} + \sum_{i^- \neq i} N_{i-j+}^{DT} + N_{jj}^{DT}$$

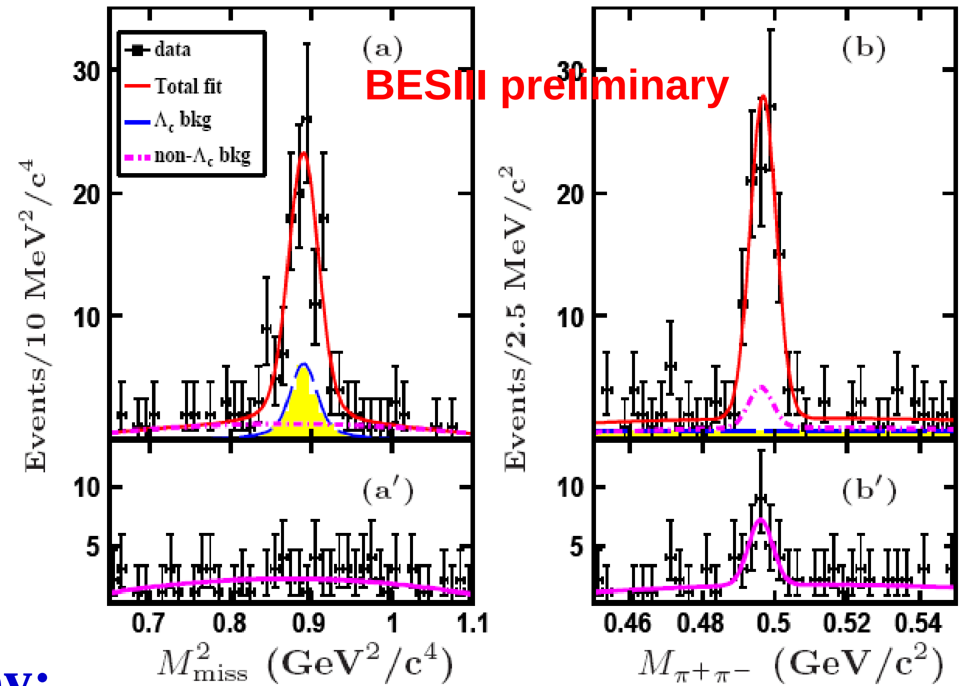
Mode	This work (%)	PDG (%)	BELLE $\mathcal{B}$
pK^0_S	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK^0_S\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK^0_S\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	

- ✓ **Absolute BFs are improved significantly.**
- ✓ **BESIII BF for $\Lambda_c^+ \to pK^-\pi^+$ is smaller.**
- ✓ **Improved absolute BF of $pK^-\pi^+$ together with BELLE's result are key to calibrate other decays.**

Observation of $\Lambda_c^+ \rightarrow nK_S^0\pi^+$

First observation of Λ_C^+ decays to final states involving the neutron.





The missing neutron is detected by:

$$\boxed{M^2_{\rm miss} = (p_{\Lambda_c^+} - p_{K_S^0} - p_{\pi^+})^2 = E^2_{\rm miss} - c^2|\vec{p}_{\rm miss}|^2}$$

Fit to $M^2_{\rm miss}$ and $M_{\pi+\pi}$ spectra in (a,b) $\bar{\Lambda}_c^-$ signal region and (a',b') $\bar{\Lambda}_c^-$ sideband region simultaneously.

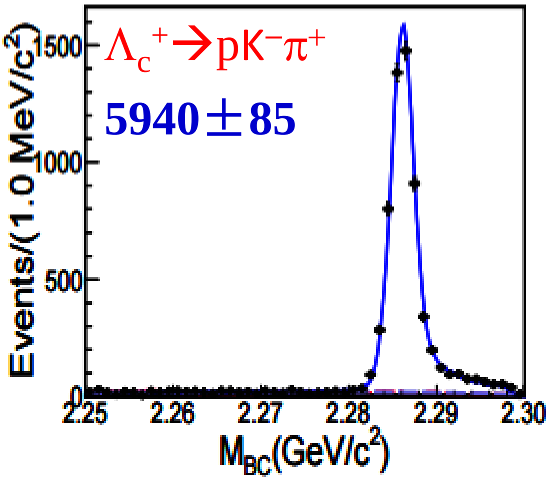
83±11 net signal events

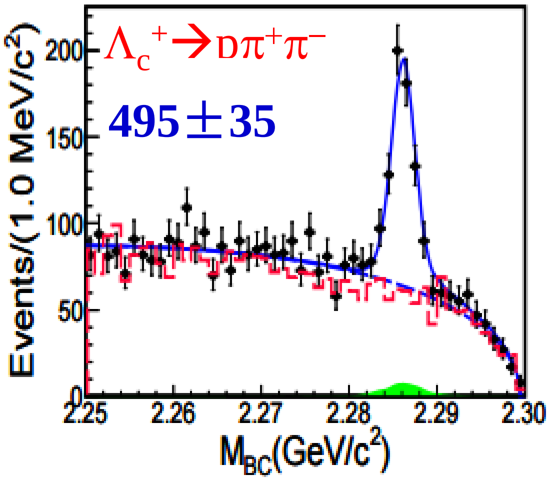
BESIII Preliminary results:

$B[\Lambda_c^+ \rightarrow nK_S^0\pi^+] = (1.82\pm0.23\pm0.11)\%$

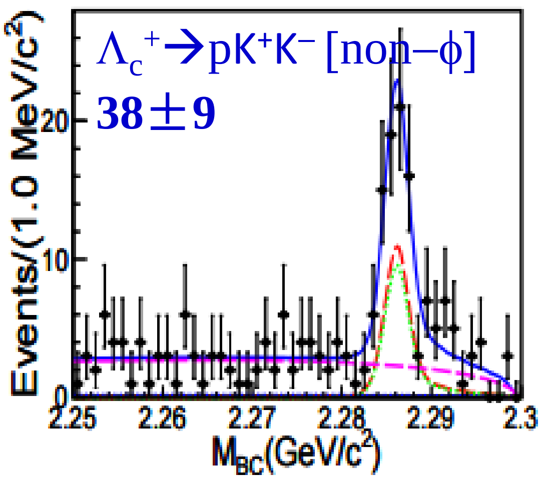
The relative BF of neutron-involved mode to proton-involved mode is essential to test the isospin symmetry and extract the strong phases of different final states. [PRD93 (2016) 056008]

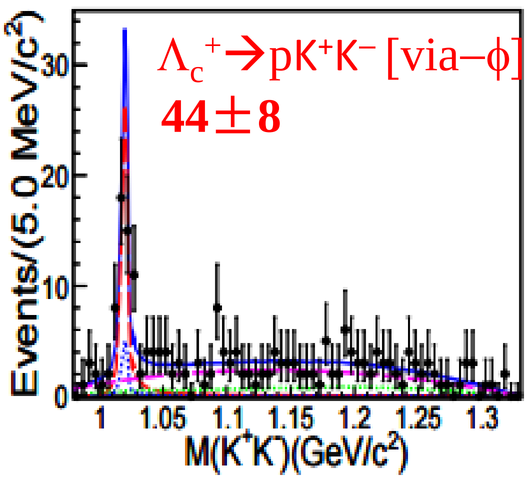
Study of SCS Decays $\Lambda_c^+ \to p\pi^+\pi^-$ and $\Lambda_c^+ \to pK^+K^-$





Two-dimensional unbinned maximum likelihood fit





Submitted to PRL arXiv:1608.00407

✓ Study of SCS decays can shed light on dynamics of Λ_c^+ decays

✓ $B[\Lambda_c^+ \to p\phi]$ is of particular interest since it proceeds W-exchange only, which is essential to validate the theoretical models and test the application of large-N_c factorization in charmed baryon.

✓ ST study, relative BFs to $\Lambda_c^+ \to pK^-\pi^+$ is measured.

✓ Input BESIII measurement:
$B[\Lambda_c^+ \to pK^-\pi^+] = (5.84 \pm 0.27 \pm 0.23)\%$

–	$\mathcal{B}_{\text{mode}}$	$\mathcal{B}$(PDG)
$\Lambda_c^+ \to p\pi^+\pi^-$	$(3.91 \pm 0.28 \pm 0.15 \pm 0.24) \times 10^{-3}$	$(3.5 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ \to p\phi$	$(1.06 \pm 0.19 \pm 0.08 \pm 0.06) \times 10^{-3}$	$(8.2 \pm 2.7) \times 10^{-4}$
$\Lambda_c^+ \to pK^+K^-$ (non-ϕ)	$(5.47 \pm 1.30 \pm 0.41 \pm 0.33) \times 10^{-4}$	$(3.5 \pm 1.7) \times 10^{-4}$

Summary

- BESIII provides important results on Λ_c^+ decays
  - Λ_C^+ Semi-leptonic decys
  - Λ_C^+ hadronic decays

  Important to understand the decay property of Λ_c^+

- More fruitful results will come out!

Thanks!